

INTERFACING MODULES FOR INTEGRATING
DISCIPLINE SPECIFIC
STRUCTURAL MECHANICS CODES

by

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The purpose of this presentation is to outline the organization and capabilities of the Engine Structures Computational Simulator (Simulator) at NASA Lewis Research Center. One of the goals of our research at Lewis is to integrate our various discipline specific structural mechanics codes into a software system which can be brought to bear effectively on a wide range of engineering problems. This system must possess the qualities of being effective and efficient while still remaining "user friendly". The simulator was initially designed for the finite element simulation of gas jet engine components. Currently, the simulator has been restricted to only the analysis of high pressure turbine blades and the accompanying rotor assembly, although the current installation can be expanded for other applications. The simulator presently assists the user throughout its procedures by performing information management tasks, executing external support tasks, organizing analysis modules and executing these modules in the user defined order while maintaining processing continuity.

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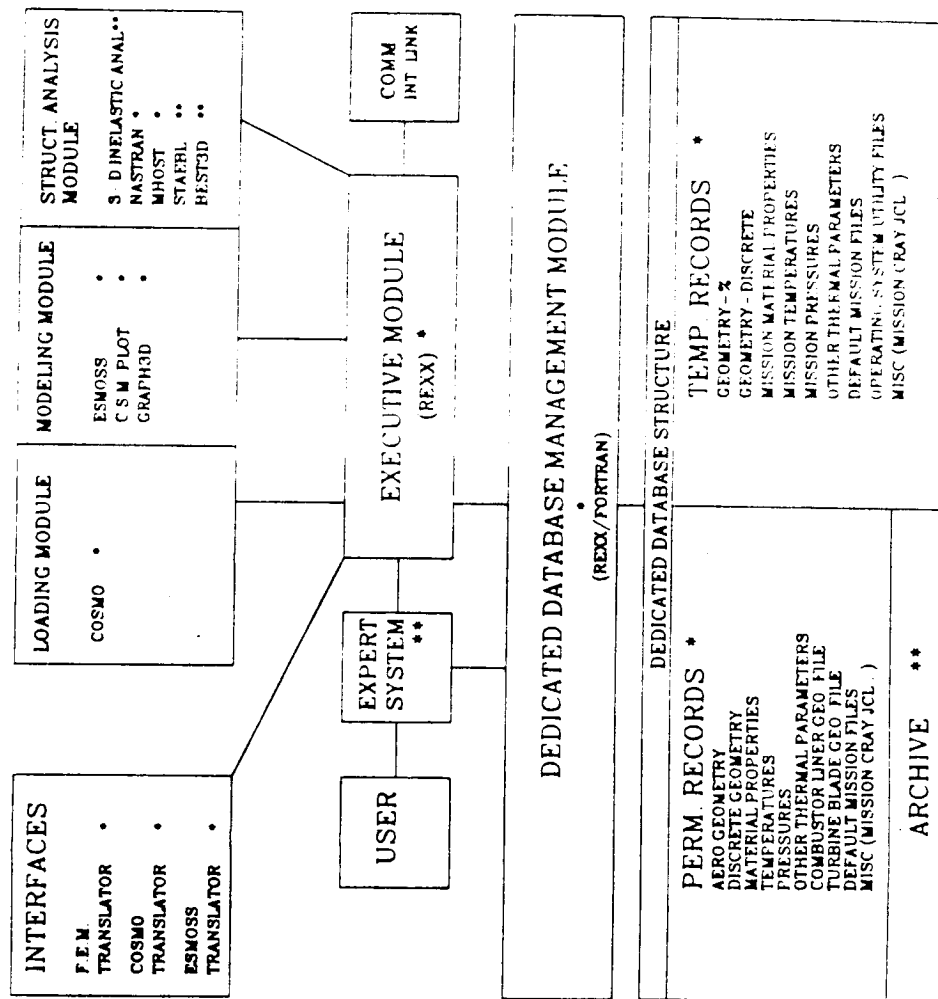
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H O W ?

How the preceding statements are accomplished will be summarized in the following presentation viewgraphs:

SIMULATOR ARCHITECTURE OF THE SOFTWARE SYSTEM



* PRELIMINARY VERSION AVAILABLE

** TO BE INSTALLED

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SIMULATOR - EXPERT SYSTEM

CAPABILITIES/FEATURES:

- 1). FORMULATION OF PROBLEM USING ACQUIRED AND USER KNOWLEDGE.
- 2). PROVIDE EXPERT OPINION AND ASSISTANCE IN FORMULATION PROCESS.
- 3). CONSTRUCT EXECUTIVE MODULE COMMANDS.
- 4). ACQUIRE AND MAINTAIN KNOWLEDGE BASE.
- 5). FORMULATE INFORMATION MANAGEMENT SYSTEM REQUESTS.

SUBMODULES:

- 1). RULE BASE.
- 2). KNOWLEDGE BASE.
- 3). INFERENCE ENGINE.

The simulator can be decomposed into three (3) distinct collections of modules; the Expert System / Executive modules, the Interface / Processing Codes and the Dedicated Database Management module / Dedicated Database. The Expert System and Executive modules dictate and maintain processing flow continuity. The Interface modules and Processing codes are the vehicle for the performance of the analysis. While the Dedicated Database Management module and Database provide and maintain the information required for the analysis.

SIMULATOR-EXECUTIVE MODULE

SETUP FACILITIES

MAIN SUBMODULE

(INTERACTIVE CAPABILITY)

(REXX)

SUBMODULES

GRAY STATION MODULE	DEFAULT STORAGE RETRIEVAL
GRAY MONITOR MODULE	COSMO PREPROCESSOR JCL
GRAY STANDBY MODULE	COSMO MISSION MODULE JCL
GRAY JCL BUILD MODULE	COSMO COMB. MODULE JCL
EXEC BACKUP MODULE	COSMO VANE MODULE JCL
F E M ANAL ASSEMBLY MOD	COSMO BLADE MODULE JCL
VIRTUAL MACHINE SCANNER	COSMO POSTPROCESSOR JCL
TEMP. STORAGE SETUP	NASTRAN PREPROCESSOR JCL
STORAGE MONITOR	HOST PREPROCESSOR JCL
VIRT. MACH. RDR SCANNER	ESMSS PREPROCESSOR JCL
EXEC BAILOUT MODULE	ESMSS POSTPROCESSOR JCL
BACKGROUND MODULE	EXEC HELP MODULE
BUFFER CHECK MODULE	HELP PLOTTING MODULE
INTRODUCTION MODULE	MENU MODULE

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SIMULATOR - EXECUTIVE MODULE

CAPABILITIES/FEATURES:

- 1). CONTROL PROCESSING FLOW.
- 2). MONITOR/INTERPRET DIRECTIVE DIALOG FROM EXPERT SYSTEM.
- 3). ASSEMBLE AND MODIFY F.E. ANALYSIS INFORMATION.
- 4). MANAGE INFORMATION FLOW BETWEEN MODULES.
- 5). ITERATIVE PROCESSING.
- 6). AUTOMATED FILE MANAGEMENT.
- 7). AUTOMATED INFORMATION RETRIEVAL SYSTEM.
- 8). AUTOMATED TEMPORARY STORAGE ALLOCATION.
- 9). MENU SELECTION OF PROCESSING FLOW.
- 10). TWO (2) F.E. CODES ARE CURRENTLY AVAILABLE: NASTRAN MHOST.
- 11). ONE (1) THERMODYNAMIC MODELLING CODE IS AVAILABLE: COSMO.
- 12). DEFAULT PROCESSING FLOW AVAILABLE.
- 13). CRAY FACILITY.
- 14). DEFAULT SAMPLE CASE AVAILABLE.
- 15). INTERACTIVE OR AUTOMATED ASSEMBLY OF F.E. ANALYSIS INPUT.
- 16). AUTOMATED TEMPORARY DISK USAGE MONITOR.
- 17). USER SELECTABLE MISSION PROFILE.
- 18). USER SELECTABLE MISSION TIME INCREMENTS.
- 19). USER SELECTABLE GEOMETRY.
- 20). TWO DEFAULT GEOMETRIES PROVIDED.

SUBMODULES:

- 1). DEFAULT STORAGE RETRIEVAL.
- 2). RESIDENT MECHANICS CODES JCL.
- 3). CRAY FACILITY.
- 4). F.E.M. ANALYSIS ASSEMBLY.
- 5). SETUP.

The primary function of the Executive module is to control the flow of the data processing within the simulator. The Executive module is composed of twenty eight (28) submodules. Each submodule performs a specific group of tasks (code execution, database data retrieval, storage monitoring, etc...) The execution of these tasks within the Executive module is controlled by interpreted Expert system commands or interactive user participation. These commands in turn lead to the execution of the Executive submodule tasks. Collectively, these submodules perform the tasks needed for the completion of the finite element analysis.

SIMULATOR—DEDICATED DATABASE MANAGEMENT

<p>MAIN SUBMODULE (REXX) (INTERACTIVE/DIRECT CAPABILITY)</p>
<p>INTERACTIVE DATA RETRIEVAL (REXX/FORTRAN 77)</p>
<p>INDEXES</p>
<p>PERMANENT RECORDS INDEXES (RESIDENT RECORDS INDEXES)</p>
<p>TEMPORARY RECORDS INDEXES (GENERATED RECORDS INDEXES)</p>
<p>DATA STORAGE PARAMETER FACILITY (COMMAND LEVEL)</p>

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SIMULATOR - DEDICATED DATABASE MANAGEMENT

CAPABILITIES/FEATURES:

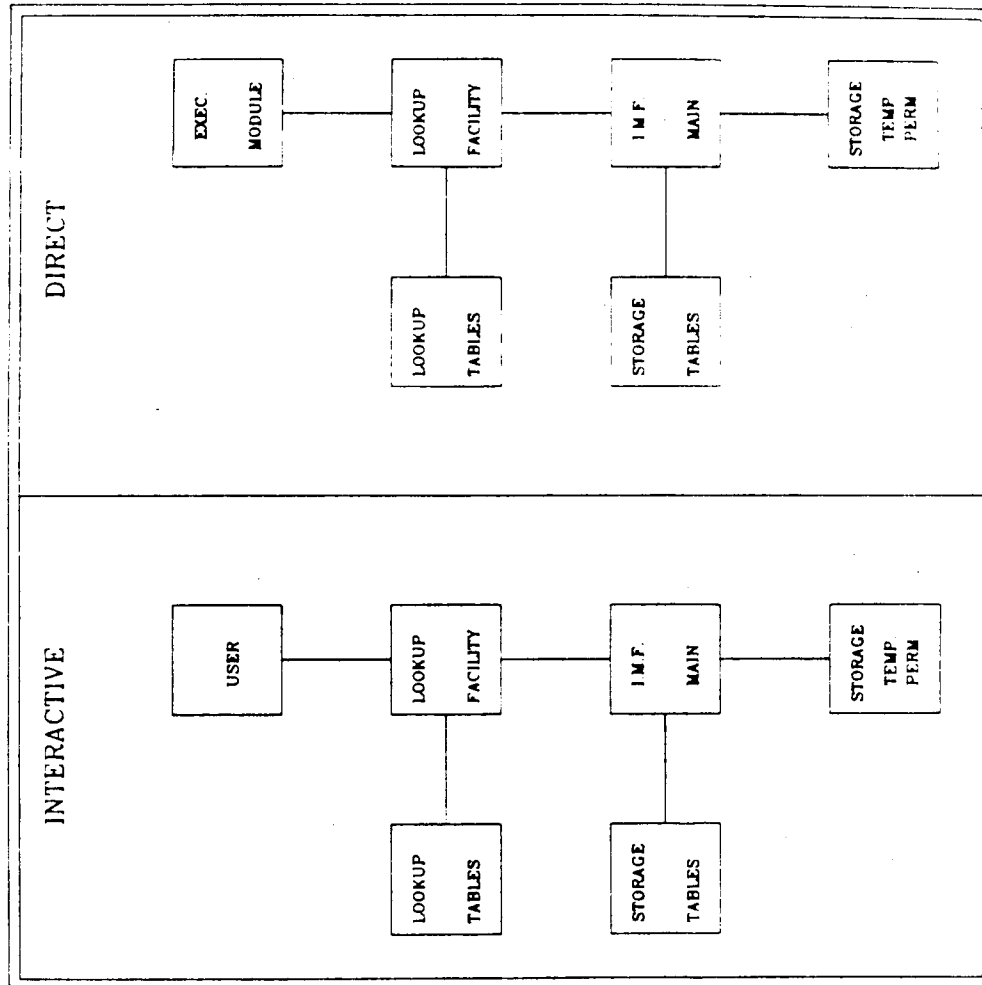
- 1). RETRIEVE AND UPDATE INFORMATION FROM PERMANENT OR TEMPORARY RECORDS VIA GENERIC INFORMATION REQUESTS.
- 2). RECEIVES GENERIC INFORMATIONAL REQUESTS FROM THE USER OR EXECUTIVE MODULE.
- 3). USES LIST DIRECTED SEARCH FOR LOCATING INFORMATION.
- 4). USER TRANSPARENT STORAGE SELECTION.
- 5). NAME ONLY REQUESTS FOR INFORMATION RETRIEVAL.
- 6). AUTOMATED LIST MANAGEMENT.

SUBMODULES:

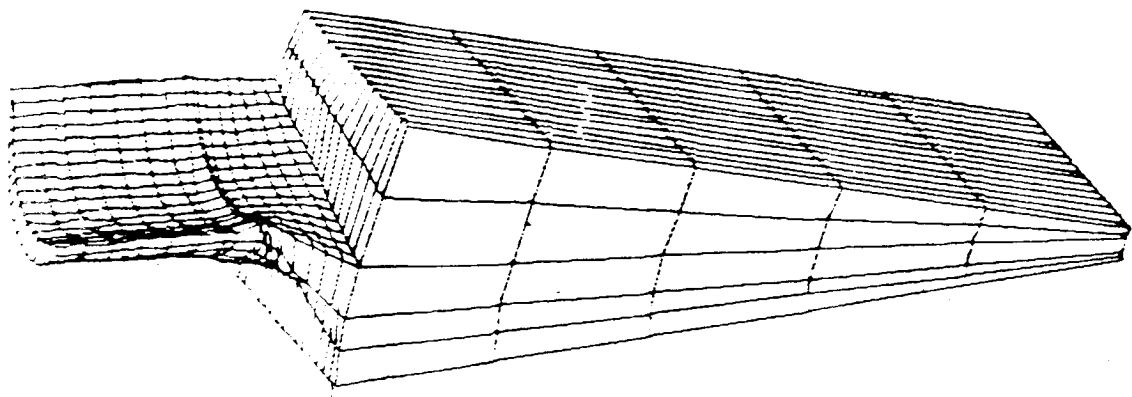
- 1). MAIN SUBMODULE (REXX).
- 2). INTERACTIVE DATA RETRIEVAL (REXX/FORTRAN 77).
- 3). RECORD AND LOOKUP INDEXES.

The Dedicated Database Management system performs the task of retrieving information from the Dedicated Database for the Executive module. This is accomplished via generic information request statements and permanent/temporary record indexes. These record indexes are maintained by the management system. An interactive retrieval system is also available to the user for the extraction of blocks of data or individual facts from the database.

INTERACTIVE DATA RETRIEVAL FACILITY



The information from the Dedicated Database can be retrieved in two methods: interactive or direct. The interactive method utilizes lookup indexes and tables in order to guide the user to the needed information. The direct method involves generic information request statements from the Executive module which directly retrieve the information from the temporary or permanent database.



This is a plot illustrating the type of information which resides within the permanent database. This figure represents a sector of high pressure turbine blade rotor assembly, a small portion of a single stage of the jet engine. This geometry and accompanying flow information can reside within the database under one generic name, in this case known as SECTOR.

SIMULATOR-DEDICATED DATABASE STRUCTURE

PERMANENT RECORDS
AERO/DISCRETE GEOMETRY DATA BLOCKS
MATERIAL PROPERTIES DATA BLOCKS
THERMOMECHANICAL LOADING DATA BLOCKS
MISC. THERMAL PARAMETER DATA BLOCKS
MISSION DESCRIPTION DATA BLOCKS
SYSTEM DEPENDENT CONTROL DATA BLOCKS
EXECUTIVE SUBMODULE DATA BLOCKS
TEMPORARY RECORDS
AERO/DISCRETE GEOMETRY DATA BLOCKS
THERMOMECHANICAL GEOMETRY SYSTEM DATA BLOCKS
MATERIAL PROPERTIES DATA BLOCKS
OPERATING SYSTEM UTILITY DATA BLOCKS
THERMOMECHANICAL LOADING DATA BLOCKS
MISC. THERMAL PARAMETER DATA BLOCKS
MISSION DESCRIPTION DATA BLOCKS
SYSTEM DEPENDENT CONTROL DATA BLOCKS
EXECUTIVE SUBMODULE DATA BLOCKS
ARCHIVE

The structure of the Dedicated Database is divided into two (2) parts; permanent and temporary records. The temporary database is constructed in temporary disc storage and is only available during Executive module execution. The temporary and permanent databases are organized into blocks of records all possessing similar qualities, such as geometry. The organization of this information is governed by the Dedicated Database management system.

SIMULATOR - DEDICATED DATABASE STRUCTURE

DATA BLOCK IDENTIFIER
DATA RECORDS ...
DATA IDENTIFIER
SECTOR GEOMETRY
DATA DELIMITER
ROTOR GEOMETRY
COMBUSTOR GEOMETRY
DATA BLOCK DELIMITER

PERMANENT RECORDS
AERO/DISCRETE GEOMETRY DATA BLOCKS
MATERIAL PROPERTIES DATA BLOCKS
THERMOMECHANICAL LOADING DATA BLOCKS
MISC THERMAL PARAMETER DATA BLOCKS
MISSION DESCRIPTION DATA BLOCKS
SYSTEM DEPENDENT CONTROL DATA BLOCKS
EXECUTIVE SUBMODULE DATA BLOCKS
TEMPORARY RECORDS
AERO/DISCRETE GEOMETRY DATA BLOCKS
THERMOMECHANICAL GEOMETRY SYSTEM DATA BLOCKS
MATERIAL PROPERTIES DATA BLOCKS
OPERATING SYSTEM UTILITY DATA BLOCKS
THERMOMECHANICAL LOADING DATA BLOCKS
MISC THERMAL PARAMETER DATA BLOCKS
MISSION DESCRIPTION DATA BLOCKS
SYSTEM DEPENDENT CONTROL DATA BLOCKS
EXECUTIVE SUBMODULE DATA BLOCKS
ARCHIVE

The structure of the temporary and permanent storage can be further subdivided groups of records within the blocks delimited by data identifiers. Between these data identifiers resides the records of current interest.

SIMULATOR - DEDICATED DATABASE STRUCTURE

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DATA RECORDS ...

DATA IDENTIFIER - SECTOR
SECTOR GEOMETRY INFORMATION
ORIENTATION OF FLOW FIELD
EXTENT OF SECTOR (NUM. OF NODES ...)
SYMMETRY INFORMATION
GLOBEL/LOCAL COORDINATES

CONNECTIVITY INFORMATION

DATA DELIMITER - \$EOD

DATA BLOCK IDENTIFIER

DATA RECORDS ...

DATA IDENTIFIER

SECTOR GEOMETRY

DATA DELIMITER

ROTOR GEOMETRY

COMBUSTOR GEOMETRY

DATA BLOCK DELIMITER

<p>PROPELLANT RECORDS</p> <p>1. PROPELLANT IDENTIFIER</p> <p>2. PROPELLANT NAME</p> <p>3. PROPELLANT TYPE</p> <p>4. PROPELLANT GRAIN DIAMETER</p> <p>5. PROPELLANT GRAIN LENGTH</p> <p>6. PROPELLANT GRAIN WEIGHT</p> <p>7. PROPELLANT GRAIN VOLUME</p> <p>8. PROPELLANT GRAIN SURFACE AREA</p> <p>9. PROPELLANT GRAIN PERIMETER</p> <p>10. PROPELLANT GRAIN CROSS-SECTIONAL AREA</p> <p>11. PROPELLANT GRAIN END AREA</p> <p>12. PROPELLANT GRAIN END PERIMETER</p> <p>13. PROPELLANT GRAIN END CROSS-SECTIONAL AREA</p> <p>14. PROPELLANT GRAIN END PERIMETER</p> <p>15. PROPELLANT GRAIN END CROSS-SECTIONAL AREA</p> <p>16. PROPELLANT GRAIN END PERIMETER</p> <p>17. PROPELLANT GRAIN END CROSS-SECTIONAL AREA</p> <p>18. PROPELLANT GRAIN END PERIMETER</p> <p>19. PROPELLANT GRAIN END CROSS-SECTIONAL AREA</p> <p>20. PROPELLANT GRAIN END PERIMETER</p>	<p>TEST POINT RECORDS</p> <p>1. TEST POINT IDENTIFIER</p> <p>2. TEST POINT NAME</p> <p>3. TEST POINT TYPE</p> <p>4. TEST POINT GRAIN DIAMETER</p> <p>5. TEST POINT GRAIN LENGTH</p> <p>6. TEST POINT GRAIN WEIGHT</p> <p>7. TEST POINT GRAIN VOLUME</p> <p>8. TEST POINT GRAIN SURFACE AREA</p> <p>9. TEST POINT GRAIN PERIMETER</p> <p>10. TEST POINT GRAIN CROSS-SECTIONAL AREA</p> <p>11. TEST POINT GRAIN END AREA</p> <p>12. TEST POINT GRAIN END PERIMETER</p> <p>13. TEST POINT GRAIN END CROSS-SECTIONAL AREA</p> <p>14. TEST POINT GRAIN END PERIMETER</p> <p>15. TEST POINT GRAIN END CROSS-SECTIONAL AREA</p> <p>16. TEST POINT GRAIN END PERIMETER</p> <p>17. TEST POINT GRAIN END CROSS-SECTIONAL AREA</p> <p>18. TEST POINT GRAIN END PERIMETER</p> <p>19. TEST POINT GRAIN END CROSS-SECTIONAL AREA</p> <p>20. TEST POINT GRAIN END PERIMETER</p>
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SIMULATOR - DEDICATED DATABASE STRUCTURE

CAPABILITIES/FEATUURES:

- 1). A TEMPORARY OR PERMANENT REPOSITORY TO MAINTAIN INFORMATION FOR USE BY EXECUTIVE AND EXPERT SYSTEM MODULES.
- 2). ITEMS OF INFORMATION ARE STRICTLY ORGANIZED AND THEIR LOCATIONS ARE DOCUMENTED.

SUBMODULES:

- 1). PERMANENT RECORDS.
- 2). PERMANENT RECORD INDEXES.
- 3). TEMPORARY RECORDS.
- 4). TEMPORARY RECORD INDEXES.

The data identifier is expressed as a simple mnemonic characterizing the contents of that group of data. This mnemonic is not used by the database management system for retrieval, but it can be used by the user to identify the contents of the database directly. The Dedicated Database Management system maintains its own set of indexes for identifying and locating information independent of the data itself. So, within the Dedicated Database there are a collection of data blocks which each contain data identifiers and data. Collectively, this information is available, and necessary, for the execution of the Executive module.

SIMULATOR INTERFACE MODULES

COSMO INTERFACE MODULES

COSMO PREPROCESSOR MODULE
 GENERIC F.E.M. INFORMATION > COSMO COMPATIBLE F.E.M. INFORMATION

COSMO POSTPROCESSOR MODULE

COSMO COMPATIBLE F.E.M. INFORMATION > GENERIC F.E.M. INFORMATION

NASTRAN INTERFACE MODULES

GENERIC F.E.M. INFORMATION > NASTRAN INPUT F.E.M. INFORMATION

MHOST INTERFACE MODULES

GENERIC F.E.M. INFORMATION > MHOST INPUT F.E.M. INFORMATION

ESMOSS INTERFACE MODULES

ESMOSS PREPROCESSOR MODULE

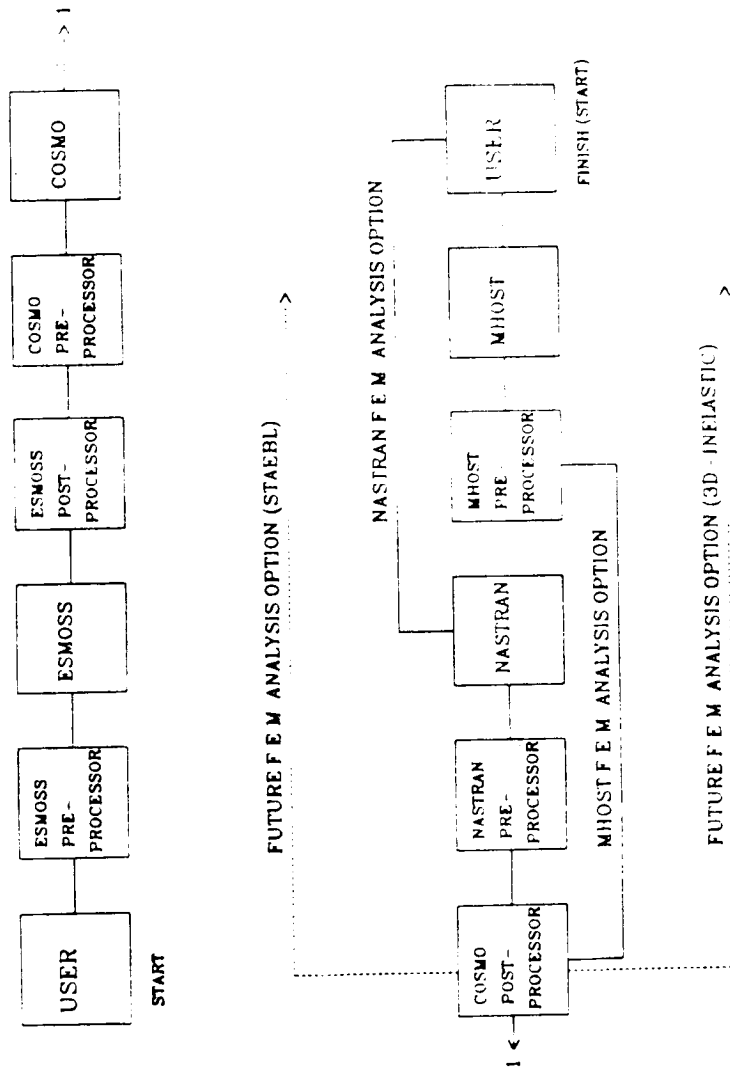
ESMOSS GEOMETRY MODELLING COMMANDS > O.S. BUFFER COMMANDS

ESMOSS POSTPROCESSOR MODULE

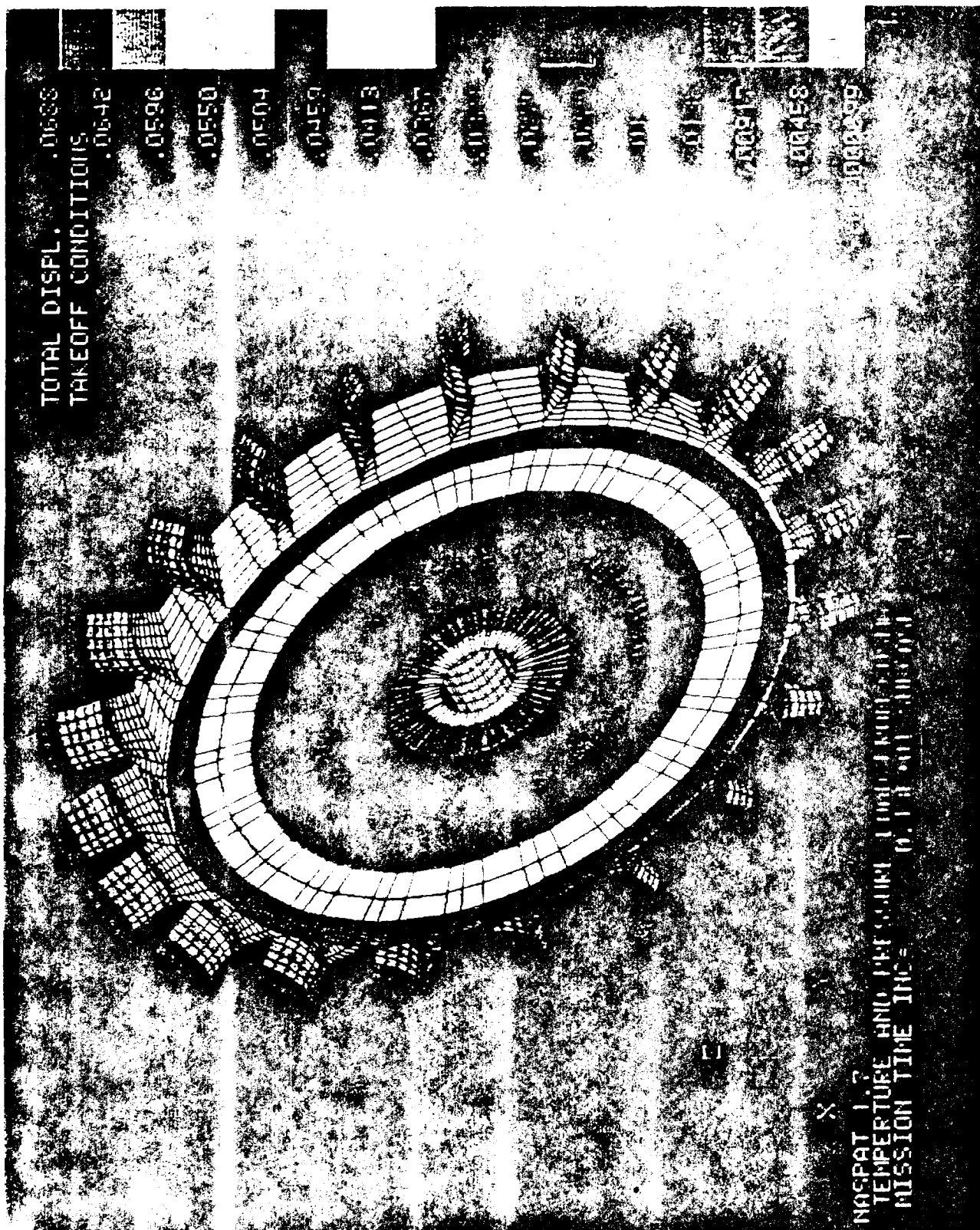
ESMOSS GEOMETRY F.E.M. INFORMATION > GENERIC F.E.M. INFORMATION

The development of the simulator in its present form was motivated by the need to incorporate several multi-disciplinary codes within a unified processing architecture. This dictated that many interface modules had to be developed for smooth transitions of information between the various codes. To this date, six (6) interface modules have been developed to handle this task. They readily translate information from generic format to code specific formats and visa versa for ESMOSS, COSMO, MHOST and NASTRAN. Additional interface modules can and will be developed to include other structural and modelling codes in the future. This capability is a major strength arising from modularity of the simulator.

SIMULATOR PROCESSING FLOW LOGIC



A sample of the processing flow logic is illustrated in the slide on the opposite page. In this example, the user formulates the finite element model with the ESMOSS preprocessor, ESMOSS and the ESMOSS postprocessor combination. Next, the thermodynamic loading for the flight is developed with the COSMO preprocessor, COSMO, and the COSMO postprocessor combination. Finally, the finite element analysis is conducted with NASTRAN or MHOST.



A sample of the type of analysis results that can be achieved are shown on the opposite page. In this case, an entire rotor-blade assembly was simulated throughout the flight with only the takeoff conditions being shown here. The slide displays the magnitude of the total displacement vector for the case of temperature, pressure and rotational loadings at takeoff condition under quasi-static equilibrium conditions. The finite analysis, in this case, was conducted with NASTRAN.